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Studies on combining ability in bitter gourd (*Momordica charantia* L.)

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Abstract
Studies on combining ability revealed that, the parent Phule Green Gold (P_1) was found good combiners and have high SCA effects for most of the characters. The four crosses *viz*., P_1 x P_2 (Phule Green Gold x Preethi), P_2 X P_5 (Preethi x DVBTG-7), P_1x P_3 (Phule Green Gold x Arka harit) and P_6 x P_7 (Hirkani x Konkan Tara) have recorded high positive SCA effect as well as high mean performance for most of the characters. Significant GCA and positive Significant SCA variances were observed for almost all the characters and the magnitude of GCA variances were lower than SCA variances for all the characters indicated preponderance of non-additive gene action.

Keywords: *Momordica charantia*, combining ability, gene action, diallel analysis

Introduction
Bitter gourd (*Momordica charantia* L.) is commonly known as karela, grown in tropical and subtropical parts of the world. Though, the bitter gourd is native of Indo-burma, it is a prized vegetable of India. It is the important member of Cucurbitaceae having higher chromosome number of 2n=22 and diploidy in nature. Being a cross pollinated crop, bitter gourd have monoecious sex form. The favourable characters of hybrids like production stability, suitability to high input agriculture, uniform growth and maturity shifted the focus towards heterosis breeding, leading to the release of the new potential hybrids. Most of the cucurbits including bitter gourd are usually produced in relatively small quantities for local consumption and so do not enter production statistics in a significant way. Nevertheless, they are important items in the diets of many people because one or more species are element of nearly every vegetable garden both home and commercial (Whitaker and Bemis, 1979) [9]. The existing varieties/land races have emerged mostly through selection from a wide variability available in this crop. The improvement of this crop thus, is mainly achieved through selection and perpetuation of better types. Combining ability analysis is important to the plant breeder as it helps in understanding the nature of gene action governing the expression of the character help in deciding upon the future breeding strategy. Development of the concept of combining which can exhibit maximum hybrid vigour in F_1. General combining ability is the average performance of the lines in hybrid combinations while the specific combining ability refers to the deviation of certain cross from expectations on the basis of the average performance of the lines involved. General combining ability include additive variance and variance arising due to additive x additive interaction, while specific combining ability includes non-additive genetic variances arising from dominance and epistatis. Though so information about combining ability of bitter gourd is available. However, to substantiate this information and to derive additional information on all the characters and also for locating all the possible combinations. More use of the available variability is required so that maximum exploitation of this phenomenon is affected. Besides, for rational improvement of yield and its components. As yield is highly complex character and many factors are responsible for the expression it is necessary to understand the mode of inheritance in governing such characters.

Material and methods
The experimental material for this study comprised seven genotypes which were selected based on the diversity for various traits. From seven genotypes twenty one crosses were obtained in diallel fashion (without reciprocals). The selected parental lines such as Phule green gold (P_1), Preethi (P_2), Arka harit (P_3), Co-white long (P_4), DVBTG-7 (P_5), Hirkani (P_6) and Konkan tara (P_7). The inbred lines of seven genotypes were selected for the purpose of

crossing programme and sown in crossing block at Instructional-Cum-Research Farm. Department of Horticulture, College of Agriculture, Latur. Crossing was made in diallel fashion (without reciprocals). The experiments were laid out in RBD with two replications having each experimental unit of single row with spacing of 1.5 × 0.5 m. The observations were recorded on parents and F_1's for twelve quantitative traits *viz*., vine length (cm), number of branches per vine, number of nodes per vine, inter nodal length (cm), days to 50% flowering, days required for first harvest, length of fruit (cm), diameter of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) and fruit yield per ha (q). The analysis of variance, for all traits under study, was carried out the method suggested by Panse and Sukhatme (1985) [4]. Data analysed for combining ability following Model I and Method II of Griffing (1956) [1].

Results and Discussion

Among the seven parents, two parents showed significant gca effects. The parent P_1 (15.24) expressed highest significant gca effects for length of vine. Similarly, results were obtained by) Ranpise (1985) [6] and Lawande (1987) [2]. The parent P_4 (1.35) depicted maximum positive gca effects for the number of branches per vine. Similarly, results were obtained by Lawande (1987) [2] and Ram *et al.* (1999) [5]. Out of seven parent only one parent P_7 (1.06) exhibited positive gca effects for number of nodes per vine. Similar, results were obtained by Ranpise (1985) [6]. The highly significant negative gca effects were exhibited by the parent P_4 (-1.20) and P_2 (-1.01) for inter nodal length. Similar, results were obtained by Ranpise (1985) [6]. The highly significant negative gca effects were exhibited by the parent P_1 (-1.11) for days to 50 per cent flowering. Similar, results were obtained by Tewari *et al.* (2001) [8]. The highly significant negative gca effects were exhibited by the parent P_6 (-1.16) for days required for first harvest. Similar, results were obtained by Ram *et al.* (1999) [5]. Among the of seven parents, only one parent P_4 (1.27) expressed highest significant gca effects for length of fruit. These results are in agreement with the finding reported by Tewari *et al.* (2001) [8]. Out of seven parents, only one parent P_7 (0.070) showed positive significant gca effects for diameter of fruit. These results are in agreement with the finding reported by Ranpise *et al.* (2001) and Tewari *et al.* (2001) [8]. Out of seven parents, only one parent P_4 (0.92) expressed highest significant gca effects for weight of fruit. Similar results have been reported by Ranpise *et al.* (2001) and Tewari *et al.* (2001) [8]. Among the seven parents, only one parent P_1 (3.47) showed positive significant gca effects for number of fruits per plant. These results were in conformity with Laxuman *et al.* (2012) [3] and Singh *et al.* (2013) [7]. The parent P_1 (0.14) showed positive significant gca effects for fruit yield per vine. Similarly, results have been reported by Laxuman *et al.* (2012) [3] and Singh *et al.* (2013) [7]. Out of seven parents, only one parent P_1 (16.05) showed positive significant gca effects for fruit yield per hectare. The estimates of SCA effects are given in Table 3. The cross combination P_1 x P_4 (98.19) expressed maximum positive significant sca effects followed by the crosses P_5 x P_7 (37.86), P_2 x P_4 (55.49), P_5 x P_6 (47.74), P_2 x P_6 (42.09) and P_1 x P_2 (41.18) for length of vine. Similarly, results were obtained by Ranpise (1985) [6] and Lawande (1987) [2]. The highest positive significant sca effects were exhibited by the crosses P_1 x P_2 (3.35) followed by P_4 x P_7 (3.01), P_4 x P_5 (1.87), P_3 x P_5 (1.70), P_2 x P_6 (1.62) and P_3 x P_7 (1.40) for number of branches per vine. Similarly, results were obtained by Lawande (1987) [2] and Ram *et al.* (1999) [5]. The cross combination P_2 X P_3 (5.07) expressed maximum positive significant sca effects followed by P_5 x P_6 (4.35), P_1 x P_4 (4.01) and P_1 x P_7 (3.84) for number of nodes per vine. Similar, results were obtained by Ranpise (1985) [6]. The 21 cross combinations studied, crosses recorded negative significant sca effects. The maximum negative significant sca effects were registered by the hybrids P_3 x P_7 (-4.32), P_2 x P_3 (-3.85), P_4 x P_5 (-3.37), P_3 X P_4 (-3.28) and P_1 x P_5 (-3.06) for inter nodal length. Similar, results were obtained by Ranpise (1985) [6]. The maximum negative significant sca effects were registered by the hybrids P_4 x P_5 (-6.26), P_2 x P_6 (-5.98), P_1 x P_3 (-5.09), P_3 X P_6 (-4.70) and P_4 x P_7 (-3.81) for days to 50 percent flowering. Similar, results were obtained by Tewari *et al.* (2001) [8]. The 21 cross combinations studied, crosses recorded negative significant sca effects. The maximum negative significant sca effects were registered by the hybrids P_2 x P_6 (-5.50), P_6 x P_7 (-5.10), P_3 x P_4 (-5.07) and P_4 x P_5 (-4.26) for days required for first harvest. Similar, results were obtained by Ram *et al.* (1999) [5]. The hybrid P_3 x P_7 (7.18) exhibited the highest positive significant sca effects followed by P_1 x P_4 (5.75), P_2 x P_3 (5.53), P_5 x P_7 (5.14), P_4 x P_6 (4.61) and P_4 x P_5 (3.06) for length of fruit. These results are in agreement with the finding reported by Tewari *et al.* (2001) [8]. Out of twenty one cross combinations studied, crosses showed positive significant sca effects. The crosses P_4 x P_5 (0.443) and P_4 x P_7 (0.271) expressed maximum positive significant sca effects for diameter of fruit. These results are in agreement with the finding reported by Ranpise *et al.* (2001) and Tewari *et al.* (2001) [8]. The cross P_1 x P_5 (7.37) recorded highest positive significant sca effects followed by P_3 X P_6 (7.01) and P_6 x P_7 (5.39) for weight of fruit. Similar results have been reported by Ranpise *et al.* (2001) and Tewari *et al.* (2001) [8]. The cross combination P_4 X P_5 (12.55) exhibited the highest positive significant sca effects followed by P_2 x P_4 (11.21), P_1 x P_2 (10.77), P_2 x P_7 (10.69) and P_6 x P_7 (10.27) for number of fruit per vine. These results were in conformity with Laxuman *et al.* (2012) [3] and Singh *et al.* (2013) [7]. The cross combination P_1 x P_2 (1.01) expressed maximum positive significant sca effects for fruit yield per vine. Similarly, results have been reported by Laxuman *et al.* (2012) [3] and Singh *et al.* (2013) [7]. As regard fruit yield per hectare, out of 21 hybrids, crosses showed positive significant sca effects. The highest positive significant sca effects were exhibited by the cross P_1 x P_2 (62.49).

Table 1: Analysis of variance for combining ability in 7 x 7 half diallel of bitter gourd

Sr. No.	Characters	GCA		SCA		Error	
		D.F.	M.S.S.	D.F.	M.S.S.	D.F.	M.S.S.
1.	Length of vine (cm)	6	947.21	21	1945.45**	28	434.02
2.	Number of branches per vine	6	3.85**	21	4.46**	28	0.39
3.	Number of nodes per vine	6	6.38**	21	8.24**	28	0.97
4.	Inter nodal length (cm)	6	9.35**	21	6.90**	28	0.79
5.	Days to 50% flowering	6	6.26	21	13.96**	28	3.30
6.	Days required for first harvest	6	5.31	21	11.34**	28	3.27
7.	Length of fruit (cm)	6	4.71**	21	14.43**	28	0.92
8.	Diameter of fruit (cm)	6	0.045	21	0.067**	28	0.019
9.	Weight of fruit (g)	6	4.03	21	27.84**	28	8.07
10.	Number of fruits per vine	6	30.74**	21	101.39**	28	6.65
11.	Fruit yield per vine (kg)	6	0.14**	21	0.73**	28	0.04
12.	Fruit yield (q/ha)	6	812.73**	21	2842.31**	28	182.96

*and ** Significant at 5% and 1% level

Table 2: Estimates of general combining ability effects for different characters in 7 x 7 half diallel of bitter gourd

Sources	Length of vine (cm)	Number of branches per vine	Number of nodes per vine	Inter nodal length (cm)	Days to 50% flowering	Days required for first harvest
P_1	15.24*	-0.44*	-0.34	1.53**	-1.11*	0.96
P_2	-6.89	0.30	0.18	-1.01**	1.11*	0.97
P_3	-9.78	-0.31	0.001	-0.24	0.33	-0.50
P_4	-6.87	1.35**	0.58	-1.20**	0.16	-0.21
P_5	-6.71	-0.21	0.12	-0.52	0.72	-0.03
P_6	12.53*	-0.53*	-1.61**	0.85**	-1.00	-1.16*
P_7	2.49	-0.14	1.06**	0.59	-0.22	-0.03
S.E.(gi) ±	6.42	0.19	0.30	0.27	0.56	0.55
C.D. at 5 %	13.19	0.39	0.62	0.56	1.15	1.14

Sources	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Number of fruits per vine	Fruit yield per vine (kg)	Fruit yield (q/ha)
P_1	-0.58	0.054	0.49	3.47**	0.14*	16.05**
P_2	0.25	0.058	0.13	0.57	0.08	3.82
P_3	-1.00**	-0.058	-0.83	-0.34	0.04	0.01
P_4	1.27**	-0.067	0.92*	0.44	0.05	3.46
P_5	-0.18	-0.097*	-0.49	-1.26	-0.24**	-13.52**
P_6	0.24	0.040	-0.65	-0.44	0.01	-1.28
P_7	0.007	0.070*	0.43	-2.44	-0.08	-8.54
S.E.(gi) ±	0.29	0.042	0.87	0.79	0.06	4.17
C.D. at 5 %	0.60	0.087	1.79	1.63	0.13	8.56

*and ** Significant at 5% and 1% level

Table 3: Estimates of specific combining ability effects for different characters in 7 x 7 half diallel of bitter gourd

Sr. No.	Crosses	Length of vine (cm)	Number of branches per vine	Number of nodes per vine	Inter nodal length (cm)	Days to 50% flowering	Days required for first harvest
1.	P_1 x P_2	41.18*	3.35**	0.21	1.92*	-2.37	-0.64
2.	P_1 x P_3	16.82	0.08	-0.19	0.43	-5.09**	0.63
3.	P_1 x P_4	98.19**	1.32*	4.01**	0.73	3.06	-1.25
4.	P_1 x P_5	-36.97	-0.68	-0.31	-3.06**	0.01	2.86
5.	P_1 x P_6	-22.38	1.27*	-0.57	-0.99	-3.76*	-2.69
6.	P_1 x P_7	1.93	-1.49*	3.84**	-0.46	-2.54	1.56
7.	P_2 x P_3	-31.08	-0.02	5.07**	-3.85**	1.68	2.62
8.	P_2 x P_4	55.49**	0.24	0.68	1.68*	0.34	1.03
9.	P_2 x P_5	-13.32	1.35*	-2.84**	1.85*	0.29	2.05
10.	P_2 x P_6	42.09*	1.62**	2.28*	-1.22	-5.98**	-5.50**
11.	P_2 x P_7	1.62	-0.13	-1.99*	1.35	2.23	2.35
12.	P_3 x P_4	-33.12	1.14	2.07*	-3.28**	3.62*	-5.07**
13.	P_3 x P_5	28.95	1.70**	1.24	0.45	2.56	2.97
14.	P_3 x P_6	-10.70	-0.84	-0.42	1.28	-4.70**	-0.63
15.	P_3 x P_7	33.85	1.40*	2.99**	-4.32**	-2.98	-2.97
16.	P_4 x P_5	2.15	1.87**	1.15	-3.37**	-6.26**	-4.26*
17.	P_4 x P_6	-16.52	1.54*	-2.91**	1.98*	4.45*	1.07
18.	P_4 x P_7	-24.80	3.01**	-1.29	-2.55**	-3.81	0.03
19.	P_5 x P_6	47.74*	-1.58*	4.35**	-2.83**	1.40	0.59
20.	P_5 x P_7	67.46**	-1.59*	0.17	0.86	0.62	-0.39
21.	P_6 x P_7	-5.22	1.41*	-2.38*	0.90	1.34	-5.10**

S.E. (sij) ±	18.69	0.56	0.88	0.79	1.63	1.62
C.D. at 5%	38.36	1.16	1.81	1.63	3.34	3.33
C.D. at 1%	45.05	1.36	2.13	1.92	3.93	3.91

*and ** Significant at 5% and 1% level

Sr. No.	Crosses	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Number of fruits per vine	Fruit yield per vine (kg)	Fruit yield (q/ha)
1.	P_1 x P_2	0.20	0.217	4.68	10.77**	1.01**	62.49**
2.	P_1 x P_3	-1.48	0.023	4.16	9.60**	0.83**	51.71**
3.	P_1 x P_4	5.75**	-0.058	0.83	2.98	0.32	15.25
4.	P_1 x P_5	0.39	0.112	7.37**	2.92	0.79**	43.65**
5.	P_1 x P_6	-1.02	0.260*	-9.96**	9.20**	-0.03	-6.80
6.	P_1 x P_7	-2.25*	0.004	-0.40	-1.05	-0.08	-9.59
7.	P_2 x P_3	5.53**	0.220	-1.94	-3.69	-0.51	-29.73*
8.	P_2 x P_4	1.96*	-0.171	3.43	11.21**	0.88**	60.33**
9.	P_2 x P_5	-1.40	0.018	4.48	8.85**	0.89**	58.43**
10.	P_2 x P_6	1.70	0.237	3.25	-1.24	0.41*	13.09
11.	P_2 x P_7	1.90*	0.231	1.58	10.69**	0.64**	47.14**
12.	P_3 x P_4	-2.90**	0.095	-4.47	7.13**	0.04	5.64
13.	P_3 x P_5	-0.37	-0.046	5.14	-2.25	0.11	7.25
14.	P_3 x P_6	-1.74	0.108	7.01*	8.52**	0.69**	51.10**
15.	P_3 x P_7	7.18**	0.007	0.45	-3.47	0.52**	15.93
16.	P_4 x P_5	3.06**	0.443**	0.56	12.55**	0.96**	61.60**
17.	P_4 x P_6	4.61**	0.092	2.53	-3.60	-0.21	-12.32
18.	P_4 x P_7	-5.59**	0.271*	2.16	-7.06**	-0.45*	-27.46*
19.	P_5 x P_6	-1.78	-0.014	-6.09*	-6.79**	-0.66**	-45.01**
20.	P_5 x P_7	5.14**	0.041	0.12	-7.80**	-0.46*	-30.85*
21.	P_6 x P_7	-2.54**	0.169	5.39*	10.27**	0.80**	58.53**
S.E. (sij) ±		0.86	0.12	2.55	2.31	0.18	12.14
C.D. at 5%		1.76	0.25	5.23	4.75	0.37	24.90
C.D. at 1%		2.07	0.29	6.14	5.57	0.44	29.25

*and ** Significant at 5% and 1% level

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